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# Subsalt Imaging – The RAZ/WAZ Experience

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## Summary

*New acquisition techniques such as wide azimuth (WAZ) and rich azimuth (RAZ), together with more accurate velocity models and migration algorithms, are being developed to meet the demand for accurate images in Gulf of Mexico subsalt exploration areas.*

*In this paper, we will share experiences gained and real data examples from processing several such surveys.*

## Introduction

Over the last decade, technology advances have significantly improved subsalt imaging capability. However, even with all the advances in imaging technology, there are many geographic areas where obtaining an image subsalt is still very challenging.

The deepwater subsalt play in the Gulf of Mexico is one such area where the cost of drilling and development can run into billons of dollars. The complex geological structures, the presence of allochtonous salt, and wells costing 50-100 million dollars or more are driving the need for a step-change improvement in technology.

Several designs for WAZ surveys are described by Moldoveanu and Egan (2006) with varying quality and cost benefits that can be modeled for individual objectives. RAZ surveys are WAZ surveys acquired in multiple directions as described by Howard et al. (2006). See Figures 1a, 1b, 1c, and 1d.

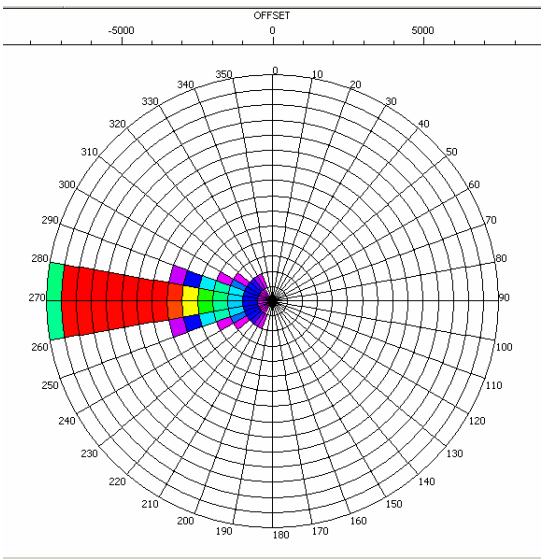


Figure 1a: Narrow Azimuth (NAZ)

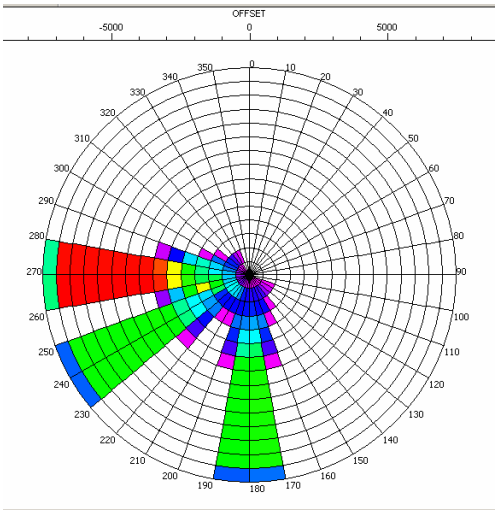


Figure 1b: Multi Azimuth (MAZ).

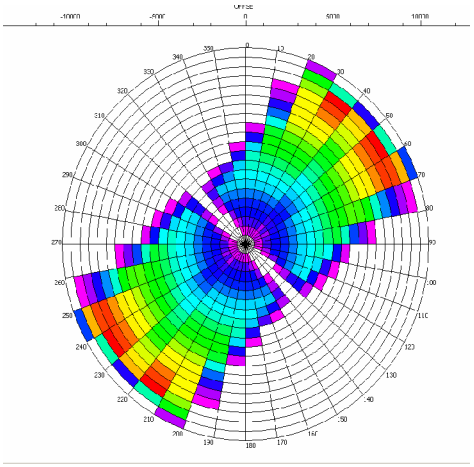

Figure 1c: Wide Azimuth (WAZ)

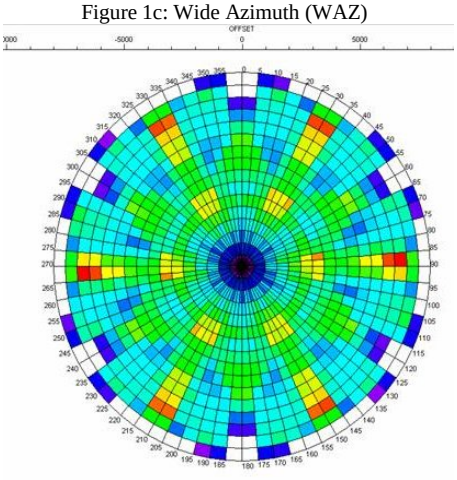


Figure 1d: Rich Azimuth (RAZ)

## Survey designs

Modeling studies have shown that these new acquisition approaches provide an opportunity for improved subsalt illumination, signal-to-noise ratio, and attenuation of multiples, compared to conventional narrow-azimuth surveys (Regone, 2006; Kapoor et al., 2006). (Figure 2).

During the past year, we have been processing four WAZ or RAZ surveys, two proprietary and two multiclient, each with a different acquisition design (Figure 3).

Survey 1 was acquired with two flip-flop source vessels front and aft and six passes of the streamer vessel (three on each side 1200, 2400, and 3600m from the source vessels).

Eight 9000-m streamers were deployed in a spread 1200m wide, yielding a 4200m crossline offset on both sides.

Survey 2 was acquired with three single-source vessels including a source on the streamer vessel in three azimuths interleaving in two reciprocal directions with source vessels 1200m across on either side of the recording vessel along with recording data during turns for additional aperture.

Ten 7000m streamers were deployed in a spread 1200m wide, yielding a 2400m crossline offset in three different azimuths

Survey 3 was acquired with three single-source source vessels 1200 and 2400m apart including a source on the streamer vessel in two reciprocal directions.

Ten 7000m streamers were used in a spread 1200m wide, yielding a 3200m crossline offset on both sides.

Survey 4 was acquired with four single-source vessels 1200, 2400, and 3600 m apart including sources on two streamer vessels interleaving in two reciprocal directions.

Ten 7000m streamers were used in a spread 1200m wide, yielding a 4200m crossline offset on both sides.

All four surveys were acquired using the WesternGeco Q-Marine system with single-sensor recording, enabling optimum noise reduction and a broader frequency spectrum at both lower and higher frequencies (King Sim Lee et al., 2006).

## Processing experience

Processing of such surveys brings its own challenges and opportunities for improved imaging.

Initial processing results with minimal processing, no multiple attenuation, and shot-domain WEM migration using an existing velocity model show that all four survey

designs lead to improved subsalt imaging over conventional narrow-azimuth surveys with full processing including multiple attenuation (Figure 4).

Data examples from testing of various design configurations using subsets of the acquired datasets will be presented at the meeting.

We will show that wider crossline offsets lead to better signal-to-noise ratio, multiple attenuation, and illumination.

Acquiring data from both directions yielded the best results because, due to feathering, obstructions and complex subsalt wavefields, true source/receiver reciprocity is not recorded.

Processing tests on Survey 1 data show better imaging using front sources vs. aft sources and front sources vs. front and aft combined. Again, this could be due to variable feather and less control of far offsets on aft sources as per Corcoran et al. (2006).

Single-source deployment allows for larger gun arrays, providing more energy penetration in subsalt regions and more accuracy in source location repeatability with multiple passes of the source vessels, which is important when performing shot-domain wavefield extrapolation migration (WEM).
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Data acquired with different azimuths exhibit differences in moveout and require multia zimuth tomography, which leads to building more accurate velocity models.

Although WAZ acquisitions geometries naturally attenuate multiples better than conventional narrow-azimuth surveys, new multiple attenuation techniques are needed to attenuate residual multiple energy. For optimum performance of SRME methods, we need sources at all receiver locations, and although interpolation techniques can be employed to fill in the necessary data, this becomes quite challenging for WAZ acquisition designs because of the sparseness of sources relative to the receivers

Another method that may be more suitable for such surveys is WEM demultiple, where we can generate the required data by predicting the multiples using a velocity model and the inverse of WEM migration, and then adaptively subtracting the multiples as per the SRME methodology.

Shot-domain WEM migration accurately represents subsalt multipaths and is quite cost effective for such surveys because data from repeatable source locations can be combined into one super shot, and thus reduce the number of shot migrations by factors of 3 to 12, depending upon the acquisition geometry. The source repeatability of our surveys was excellent with over 90% of the shots within 20 m of each other.

## Conclusions

Wide- and rich-azimuth surveys provide a step change improvement in subsalt imaging.

These surveys improve signal-to-noise ratio and illumination in complex subsalt geology.

Multi azimuth tomography improves velocity models.

Such surveys naturally attenuate multiples better than narrow-azimuth surveys.

These surveys are not a silver bullet. There are still areas where subsalt images are quite poor and further improvements are still needed.

## Acknowledgments

The authors would like to thank Cris Corcoran and team at Shell, Mike Howard and team at BHP Billiton, Hess corporation, Repsol-YPF and colleagues at WesternGeco for their collaboration and the management of above companies for permission to present data examples from their projects.

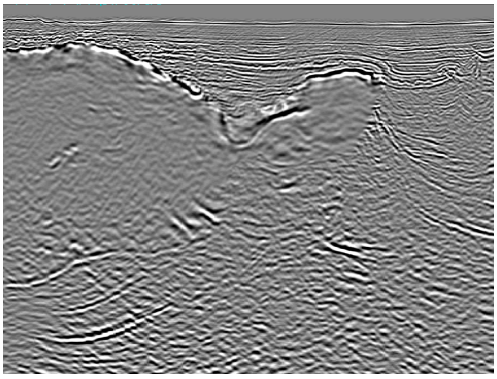

Figure 4a: NAZ data with multiple attenuation

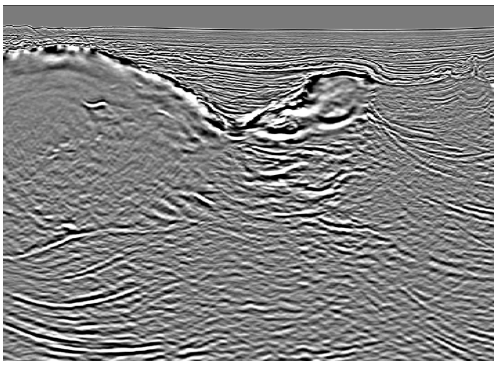

Figure 4b: WAZ data without multiple attenuatio